

550.1
F16

THE LENGTH OF GEOLOGIC TIME.

BY HERMAN LEROY FAIRCHILD.

The problem of the Earth's age has a peculiar interest, none the less from its uncertainty, and improbability of exact solution. The most frequent question asked the geologist is one relating to time. How many years ago was this or that event or phenomenon?

The problem has been approached from two directions; by the geologists, basing estimates upon the present rate of land destruction and marine sedimentation, as applied to the total thickness of sedimentary rocks; and by the physicists, calculating from the laws of matter and radiant energy the time required for cooling and condensation of the earth. The geological method, resting upon the theory of uniformity, is simple, but the data are complex and elusive; the physical method has to make large assumptions regarding the behavior of matter under conditions of heat and pressure transcending all experience.

Estimates upon the length of geologic time have been made by many geologists. When the uniformitarian theory came into general acceptance, a half century ago, and it was recognized that the earth,

as we see it, is the result of steady action of the same geologic forces and agencies that are working to-day, it was naturally believed that the age of the earth must be of indefinite duration. For merely the sedimentary rocks a minimum time of hundreds of millions of years was claimed. For the pre-Silurian and crystalline rocks, and the preceding molten stage of the earth no limit could be given. This was the inevitable swing of the intellectual pendulum away from the catastrophic or cataclysmic theory and the Biblical chronology.

To these extreme views a check was given by the physicists. In 1862 Sir William Thompson challenged the geologists by announcing that from the laws of heat radiation not over 100 millions of years could be allowed for the cooling of the earth to its present condition from a fluid state. Other physicists later gave much less range of time. The geologists were led to moderate their claims, and to make closer estimates, until now there is substantial agreement between the two classes of scientific men.

By a comparison of the character and amount of sediments the relative lengths of the great geologic time divisions are not difficult to approximate. But a determination in years is difficult because of the lack of any constant quantity with time value. As a time unit various phenomena have been taken; the rate of degradation of the continents; the growth of river deltas; the formation of river canyons; and the amount of rock disintegration and stream erosion since the ice invasion in our northern lands. The results are confessedly inexact, but have a fair agreement.

In the past year three important essays upon the subject have appeared, one from the physical standpoint, and two from the geological. In the January, 1893, issue of the *American Journal of Science*, Mr. Clarence King revises the physical conclusions in the light of new data upon the behavior of diabase rock under experimental conditions of heat and pressure. His conclusion is that the age of the earth since its molten state cannot be over 24 million years. An article by Mr. Warren Upham in the March, 1893, number of the same journal, reviews the arguments and estimates of earlier writers, and favors 48 million years for our stratified rocks (since beginning of Cambrian time), or 100 millions for geologic time (since the ocean existed). The Vice-Presidential Address of Mr. C. D. Walcott before Section E of the American Association for the Advancement of Science, at Madison, Wisconsin, in August last, was printed in the *American Geologist* in December. By a careful and detailed study of

the sedimentary rocks of Paleozoic time in western America as a basis for comparison and computation, and modifying the time ratios of Haughton and Dana, he concludes that post-Archean time is between 25 to 30 million years as a minimum, and 60 to 70 million years as a maximum. More definitely he gives 27,650,000 years for the fossiliferous rocks and 55 million years for geologic time (since the beginning of the Archean).

Following is a table of estimates of various writers, the physicists placed last. The first column gives those estimates which cover only the time of the fossil-bearing or unaltered sediments, that is, since the beginning of Cambrian time. The second column gives those estimates which include all of "geologic time," that is, since the beginning of the Archean, or since the present agencies began their work. This time would be covered by the existence of the ocean. The third class of estimates are those which cover all the duration of the earth since a state of extreme heat. The estimates of the physicists fall into this third class.

		For fossiliferous sediments.			For existence of ocean.
(¹)	Sir Charles Lyell.....	240 million years.			
(²)	Dr. Samuel Haughton...	133	"	"	200 million years
(³)	Dr. James Croll.....	60	"	"	72 " "
(⁴)	Dr. Charles Darwin.....				200 " "
(⁵)	Sir Alfred Wallace.....				28 " "
(⁶)	Sir Archibald Geikie....	100	"	"	
(⁷)	Mr. T. Mellard Reade...	95	"	"	
(⁸)	Prof. J. D. Dana.....	48	"	"	
(⁹)	Prof. Joseph LeConte...	30	"	"	
(¹⁰)	Mr. Warren Upham.....	48	"	"	100 " "
(¹¹)	Mr. C. D. Walcott.....	28	"	"	55 " "
(¹²)	Mr. W. J. McGee.....	2400	"	"	

BIBLIOGRAPHIC REFERENCES.

- (1) Lyell:—"Principles of Geology," 10th Ed., 1867, Vol. 1, p. 301.
 (2) Haughton:—"Six Lectures on Physical Geography," 1880, p. 94; *Philos. Mag.*, XXVI, Dec., 1877, p. 545.
 (3) Croll:—"Climate and Time," 1875, p. 342.
 (4) Darwin (Chas.):—"Origin of Species," 5th Ed., 1871, p. 291.
 (5) Wallace:—"Island Life," 2d Ed., 1892, pp. 222-223.
 (6) Geikie:—"Presidential Address," 62d Meeting Brit. Assoc. Adv. Sci., 1892; (*Nature*, Aug. 4, 1892, and in *Smithsonian Report* for 1892).
 (7) Reade:—"Geological Magazine," Vol. 10, 1893, pp. 99-100.
 (8) Dana:—"Manual of Geology," 3d Ed., 1880, pp. 590-591.
 (9) Le Conte:—"Elements of Geology," 1888, pp. 275-276.
 (10) Upham:—"Amer. Jour. Sci.," Vol. XLV, March, 1893, pp. 209-220.
 (11) Walcott:—"Amer. Geologist," Vol. XII, December, 1893, pp. 333-368.
 (12) McGee:—"Science," June 9, 1893, p. 309.

		Since molten state.
(¹³) Prof. A. de Lapparent.....	80	million years.
(¹⁴) Dr. Alexander Winchell.....	3	" "
(¹⁵) Sir William Thomson.....	100	" "
(¹⁶) Prof. George H. Darwin.....	57	" "
(¹⁷) Prof. Guthrie Tait.....	10	" "
(¹⁸) Prof. Simon Newcomb.....	14	" "
(¹⁹) Mr. Clarence King.....	24	" "

Excluding the two extreme estimates in the above table, it will be seen that the late estimates are in fair agreement and, as compared with former views, are reasonably definite. There is substantial agreement not only among the geologists, but between the geologists and the physicists.

Estimates of the relative duration of the greater geologic time divisions have been made as follows :

	Paleozoic.	Mesozoic.	Cenozoic.
Dana.....	12	3	1
Winchell.....	9	3	1
Williams, H. S.....	15	3	1
Walcott.....	12	5	2

Mr. Walcott's estimate, according to his proportion given above is, for the Paleozoic, 17,500,000 years ; Mesozoic, 7,240,000 years ; Cenozoic, 2,900,000 years ; total for the fossiliferous sedimentary rocks. 27,650,000 years.

The time since the departure of the ice of the Glacial period from this portion of the continent has been estimated by several eminent authorities, from different data, and their figures fall within 6,000 to 10,000 years.

(13) de Lapparent:—*Bull. Soc. Geol. France*, 3d Ser., Vol. 18, 1890, pp. 351-355.

(14) Winchell:—"World Life," 1883, p. 378.

(15) Thomson:—*Trans. Roy. Soc. Edinburgh*, Vol. XIII, Pt. 1, p. 157 ; "Treatise on Natural Philosophy" (Thomson and Tait), Appendix D.

(16) Darwin (G. H.):—*Phil. Trans. Roy. Soc.*, Pt. 2, 1879.

(17) Tait:—"Recent Advances in Physical Science," 3d Ed., 1885, p. 169.

(18) Newcomb:—"Popular Astronomy," pp. 505-519.

(19) King:—*Amer. Jour. Sci.*, Vol. XLV, January, 1893, pp. 1-20.